

Interactive comment on “Contrasting thinning patterns between lake- and land-terminating glaciers in the Bhutan Himalaya” by Shun Tsutaki et al.

Anonymous Referee #2

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This manuscript presents measurements of areal and surface elevation change, satellite-derived surface velocity data and modelled mass balance and ice dynamics data for three glaciers in the Bhutan Himalaya. One of these glaciers is land-terminating, another is transitioning between land-terminating and lake-terminating, and the third is lake-terminating. The ultimate goal is to be able to test whether proglacial lake development leads to increased glacier thinning rates. The conclusion is that it does, and that the glacier transitioning from land- to lake-terminating will accelerate and thin further as the proglacial lake develops. The manuscript is well-written, appropriately and clearly structured and the figures are good quality, but further work is required before it can be published in The Cryosphere.

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Major comments:

1. My main concern relates to the lack of any real sensitivity testing to the many components that are assumed or estimated in the modelling – particularly relating to the surface mass balance. The stated uncertainty in the thermal resistance calculations are > 60 % alone... As a minimum it would be helpful to see the output from the debris thickness modelling to see if it is realistic. There are further assumptions relating to the linear temperature profile and albedo, for example, that need to be accounted for since the estimated mass balances are very negative compared with previous studies. How much impact are these terms having on the results? The ice flow modelling is simple, which is not a problem in itself, but certainly it would help to see some of the input datasets such as the ice thickness map to convince the reader it is somewhat realistic. And what impact does the chosen sliding coefficients have on the modelled results (beyond figure S3)?

2. The main conclusion of the manuscript is, as I understand it, that lake development does impact ice dynamics, and therefore thinning rates. I didn't get this from first reading, mainly because the two glaciers on which the manuscript focuses (Thorthormi and Lugge) are not easy to compare – they have very different geometries, different debris distributions, and different flow regimes (even before accounting for lake vs no-lake). Given this, perhaps spending a bit more time looking at the lake- vs no-lake simulations for Lugge Glacier might help (the latter of which is given little attention at present). And/or looking further at what has happened at Thorthormi following lake development (see point 4 below). There are also several statements about the low impact of ice dynamics on the thinning rates of Lugge Glacier, yet a final forecast of rapid changes at Thorthormi Glacier once the lake develops – how can these two assertions be reconciled? Is it that emergence velocity at Lugge would be (more) positive in the absence of a lake? Overall, spending some further time sharpening the take-home message would be beneficial.

3. Somewhere it needs to be explicitly acknowledged that this is a very (very) small

sample. While the field data clearly cannot be replicated, an abundance of satellite remote sensing data are available to test some of these ideas across the broader Lunana area. I acknowledge this would require significant further data processing, but augmenting the dataset would certainly give the study more substance.

4. The forecast for an impact on ice dynamics at Thorthormi is interesting, but represents a missed opportunity I think. Why not test this prediction, using velocity (and perhaps also surface elevation) data derived from more recent satellite imagery (it has been 7 years since detachment from the terminus). If this analysis does indeed show that the glacier has accelerated and thinned, it would add great weight to the existing conclusions.

Minor comments (per line number)

1-5: these two sentences are almost identical. Suggest rewording one or the other.

5: spell out GPS in full

6: move 'for the 2004-2011 period' to end of sentence

12: does it really 'more than offset' glacier thinning? Surely this would result in thickening? Suggest 'compensates'...

24: insert 'particularly' before 'sensitive' given that all glaciers are impacted by changes in temperature and precipitation

28: remove 'therefore' given this sentence is not substantiated by preceding text

29: what is meant by 'mechanisms' – this is rather vague...

47: spell out GPS at first use in main text

54: I'm not sure remote sensing methods can't measure several metres of change. How about lidar? Suggest change to 'small' changes in surface elevation.

55: change 'sub-metre' to 'centimetric'?

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57: change 'performed' to 'acquired'

59: remove 'rapid' since no results have been presented at this stage of the manuscript

63-64: yes, but the glaciers are entirely different in geometry – some better justification for site selection is required here

65: using 'dynamic thinning' here is pre-emptive – it could be thickening too... maybe change to 'dynamics'?

65-66: change 'the surveyed glacier thinning' to 'changes in glacier surface elevation'

72: is this thinning rate a mean value for the ablation area? Needs specifying.

75: is this what defines a land-terminating glacier? Does whether it is grounded or floating not represent a better criterion?

101 and elsewhere: I'm not sure what TCD protocol is for referencing web pages but this is awkward – can the full url not be put in the reference list?

112: very few points of elevation change are shown in Figure 1... where can I see these 431, 248 and 258 points?

114: 'off-glacier' should be hyphenated

119: specify the sample number is 'n'

125: comment on the quality of the co-registration?

131: how can a single window size of 16 x 16 pixels be multi-scale?

136: replace 'aerial' with 'areal'

141-143: why exclude the ponds? Would these not have ice beneath or do you think they have melted down to bedrock? Does this explain the very odd digitising of glacier area presented in Figure 4a?

152: change 'calculated' to 'estimated' given there are many uncertainties in the mod-



159: that's a large uncertainty. How does it propagate through for the rest of the modelling?

230: make it clear here that you're simulating a lake-free Lugge Glacier – I read this that at present the lake is frozen! Suggest 'For Lugge Glacier, we simulate a lake-free situation, with ice flowing to the contemporary terminal moraine' or similar

315-316: are these both '-3 to 0 m a-1' by coincidence or is there a typo?

341-342: but you go on to show that dynamics only play a minor role in thinning at Lugge... are you suggesting dynamics were more important following initial lake development?

344: specify this is 'simulated' SMB...

427: does this statement that dynamic thinning is small at Lugge not undermine the main take-home message of the manuscript?

537: replace 'Mörg' with 'Mölg'...

Figure 1: can you indicate the ponds that ultimately coalesce into a lake on Thorthormi?

Figure 3: can you be sure these data towards the terminus of Lugge are not tracking the recession of the ice-front? How do you avoid matching the ice-front (i.e. the dominant feature) in these locations?

Figure 4: how were these outlines derived? They look very odd to me, with no obvious distinction in the debris-cover around any of the digitised outlines...

Interactive comment

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